Detecting, Measuring the Position and Velocity of Objects on the Wheeled KRSBI Robot Barelang 63

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Abstrak

Robot KRSBI beroda merupakan robot yang dirancang untuk bisa bermain sepak bola layaknya seperti manusia pada umumnya, adapun mekanisme penggerak utamanya berupa roda. Robot sepak bola beroda dibedakan menjadi dua yaitu robot penyerang yang memiliki tugas untuk mencetak gol ke gawang lawan dan robot penjaga gawang yang bertugas untuk menjaga gawang supaya tidak terjadi gol ke dalam gawang. Pada era revolusi industri seperti saat ini banyak robot yang mengalami peningkatan dalam hal kecerdasan buatan, dalam proposal ini penulis mencantumkan beberapa sistem yang diangkat sebagai penulisan proposal tugas akhir diantara lainnya adalah, pengukuran posisi objek dan kecepatan objek. Agar robot mampu untuk mendeteksi objek, mengukur posisi jarak objek, mengukur *velocity* objek, maka robot akan menggunakan sebuah sensor kamera *stereo.* Dengan kondisi pencahayaan pada ruangan menjadi permasalahan yang ada. Hal ini diangkat pada penulisan tugas akhir ini bermaksud untuk mengembangkan sistem pada robot agar lebih memiliki kemampuan yang mumpuni pada saat bertanding. Pada penelitian ini sistem yang dikembangkan menggunakan *ZED Camera* dan *TINY YOLO V3 deep learning*, performa yang dihasilkan dengan menggunakan sebuah laptop MSI dengan spesifikasi yang memiliki kartu grafis NVIDIA GTX 1660 TI adalah sebesar 100 FPS. Setelah melakukan percobaan untuk mendeteksi semua objek (bola *orange*, gawang, tiang gawang, warna *cyan,* warna *magenta,* dan penghalang) tingkat akurasi rata-rata sebesar 88,12% dan nilai mAP 95.99%. Kemudian sistem pengukuran jarak dan *velocity* akan mengukur jarak objek dan kecepatan objek terhadap kamera dengan hasil sistem pendeteksian. Dari berbagai percobaan, sistem pengukuran jarak mampu mengukur jarak pada jarak 100 sampai 1000 cm.
Kata kunci: Object Position and Velocity Measurement, Object Detection.

Abstract

The KRSBI wheeled robot is a robot designed to be able to play soccer just like humans in general, while the main driving mechanism is in the form of a wheel. The wheeled soccer robot is divided into two, namely the attacking robot which has the task of scoring goals against the opponent's goal and the goalkeeping robot whose job is to guard the goal so that no goals occur into the goal. In the era of the industrial revolution, such as today, many robots have increased in terms of artificial intelligence, in this proposal the author lists several systems that are appointed as the writing of a final project proposal, among others, measuring object position and object velocity. So that the robot is able to detect objects, measure the position of the objects distance, measure velocity object, then the robot will use a stereo camera sensor. With the lighting conditions in the room there are problems. This matter is raised in the writing of this final project intends to develop a system in the robot so that it has more capable abilities when competing. In this study, the system developed using a ZED Camera and TINY YOLO V3 deep learning, the performance produced by using an MSI laptop with specifications that have an NVIDIA GTX 1660 TI graphics card is 100 FPS. After doing an experiment to detect all objects (balls orange, goals, goalposts, cyan color, magenta color, and obstacles) the average accuracy rate is 88.12% and the mAP value is 95.99%. Then the distance measurement system and velocity will measure the distance of the object and the objects velocity to the camera with the results of the detection system. From various experiments, the distance measurement system is able to measure distances at a distance of 100 to 1000 cm.
Keywords: Object Position and Velocity Measurement, Object Detection.

1. Introduction

Currently the Barelang 63 robot has three robots, namely two attack robots and one goalkeeping robot. For the attacking robot, the main task is to score as many goals as possible into the opponent's goal, with safe conditions for the striker robot itself, and the surrounding environment when competing. Meanwhile, the goalkeeping robot has a duty as a goalkeeper from opponent attacks so that goals do not occur in the goal itself.

The goalkeeping robot must have the ability to block the ball into the net from the opponent's attack (ball interception). The goalkeeping robot must also have capable skills in terms of positioning, this is because the robot must remain in the goal guard area from the opponent's attack, in addition to the two previous abilities that the goalkeeping robot must have is to keep the ball away (kicking ball). The goalkeeping robot must have this which aims to keep the ball away from the guarding area and minimize additional attacks from the opposing robot.

In a wheeled soccer robot, especially with a striker robot, one of the things the robot must have is kicking the ball and dribbling the ball, in the Barelang 63 robot currently the system of kicking the ball uses a solenoid (coiled wire). In terms of kicking a ball, the robot must also have the ability to determine the target for the execution of kicking the ball or passing the ball. The Barelang 63 robot must also be able to make decisions to kick the ball, because there will be times when it is about to kick the ball there are obstacles that hinder the process of kicking the ball so that the ball that was kicked before does not enter the opponents goal.

The Barelang 63 wheeled soccer robot when kicking, and carrying the ball must maximize it so that it can score goals without the ball being taken by the opponent, this is what requires the wheeled soccer robot to have the ability to avoid obstacles, the process of avoiding obstacles begins with detection obstacle , the robot must be able to know the existence obstacle detected on the right or left side of the robot, then proceed with making direction decisions by dodging movements in the safest direction to reach the goal by continuing to maintain the ball being carried.

Of the various basic abilities that the wheeled soccer robot that has been described previously. The most basic of all intelligence capabilities, namely the wheeled soccer robot must be able to detect and distinguish objects. In Barelang 63 wheeled soccer robot, the object detection system used is TINY YOLO V3 YOLO (You Only Look Once). Followed by the development of intelligence that this wheeled soccer robot must have is to be able to measure the distance from the detected object and measure speed (velocity). This is a development of the object detection system that is owned by YOLO (You Only Look Once), which aims to increase the intelligence that robots have.

All the intelligence systems described earlier will also not work optimally, if in the process of designing and manufacturing the robot mechanics there are still many shortcomings as a whole. In designing the mechanical system, it has an influence on the movement of the robot itself, and it cannot be separated from the choice of strategy or algorithm to be used. Currently the Barelang 63 robot has implemented an algorithm that utilizes the detection of various objects in the field to make decisions on the robot.

At current conditions, the Barelang 63 robot still has several shortcomings, namely the robot is not yet capable of detecting objects properly, measuring object distances, and knowing velocity object.

From some of the problems above, the writer wants to do some research to solve some of the shortcomings of the Barelang 63 robot so that the robot has a good ability to play in the competitions that have been held, and the author also wants to improve the system capabilities that the robot previously had. With this research, the writer can draw some problem formulations as written in the next sub-chapter.

2. Detect, Measure Position and Velocity Object

A. Object Detection Method

The method used to detect an object on the playing field is TINY YOLO V3, this method is used in robots because the robot requires a detection system that has a fairly high level of accuracy and is able to work in many light conditions. TINY YOLO V3 is a method that uses the system Deep Learning in it, where deep learning alone can learn a case by itself. Deep Learning as known as Deep Neural Network, this method is able to operate and manage large amounts of data because it has used a lot layer (network layer). YOLO differs from other detection methods such as R-CNN and Faster R-CNN, where the two methods are per-target detection systems [1]. While TINY YOLO V3 apply the network layer to the entire image to be studied by dividing the areas in the image and then predicting a bounding box (bounding boxes), TINY YOLO V3 only use one bounding box neural network and the probability value in each class The object is then immediately evaluated once for one full size image, so that the resulting performance during the detection process is 45 FPS (frames per second) [2]. TINY YOLO V3 will be applied to both cameras on the attacking robot and one camera on the goalkeeping robot, for di stereo camera YOLO needs Software Development Kit (SDK) that has been provided by Stereolabs to support functions that will later be used in program.

B. Object Distance Measurement Method

To find out the distance of the object, the camera used is stereo camera. Stereo camera used is ZED Camera the first version, this camera has a detection range of distances to objects ranging from 0.3 meters to 25 meters and this camera also has a field of view (Field of View) a maximum of 90 ° (H) x 60 ° (V) x 100 ° (D). So that it allows the robot to detect the distance from objects more widely and accurately, this camera is also integrated with Linux Ubuntu, OpenCV, and TINY YOLO V3 through the SDK that has been published by Stereolabs. Therefore, the method used to measure the distance of the detected object is to use the method comparison of the values of the X, Y, and Z coordinates Centroid three dimensions that have been obtained at the time of object detection [3]. In Figure 1, you can see the optical axis of the polar epi geometry that is on stereo camera to find the value on the Z axis, where there are two center points between the camera on the left and the camera on the right. With congruence $\Delta P\, C_L\, C_R$ and $\Delta P_L\, P_R$ triangle [4].

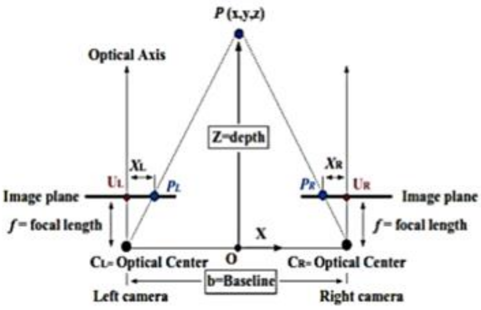

Figure 1. Optical Axis Polar Epi Geometry [4].

From Figure 1, the following equation can be found:

$$\frac{b}{z} = \frac{(b + xr) - xl}{z - f} \quad (1)$$

$$z = \frac{b * f}{xl - xr} = \frac{b * f}{d} \quad (2)$$

Where d is value *disparity*, xl is the x coordinate on the camera on the left, xr is the x coordinate on the right camera, b is the length between the center of the two cameras and f is *focal length* on both cameras. The greater the value *disparity* the closer the object is to the baseline of the camera [4]. After obtaining the three coordinates desired, to find the distance between the robot and its object, the following equation can be obtained:

$$d = \sqrt{x^2 + y^2 + z^2} \quad (3)$$

The distance obtained is in centimeters, because the values of the X, Y, and Z axes are already in centimeters.

C. Object Velocity Measurement Method

The method used to measure velocity object to the robot is to use a method using a method velocity measurement method [5] by comparing the shift in position with a time difference. In Figure 2 it can be seen that the object is moving in the X, Y, and Z plane, assuming the robot and object are moving freely in that plane starting from time T1 to T2, then it will produce a position displacement ΔS, so that the time difference is ΔT[5].

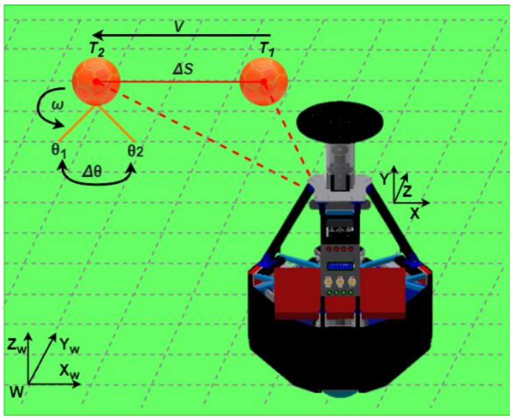

Figure 2. Schematic Diagram of Measurement Velocity.

So that there is an equation instantaneous scalar velocity as follows:

$$v = \frac{\Delta S}{\Delta T} \quad (4)$$

The change in the angle of the moving object is $\Delta\phi$, so that *instantaneous angular velocity* as follows:

$$\omega = \frac{\Delta\phi}{\Delta T} \quad (5)$$

To count velocity which is the real object, assume the coordinates of the moving object are $(x1, y1, z1)$ at time T1, $(x1', y1', z1')$ at time T2. For the Y-axis displacement, it will occur if an object such as a sphere will move upwards from the surface of the plane, while for other objects the Y-axis will not exist because the object is moving on a flat plane, even if the Y-axis has a value for objects other than the sphere, it will produce a calculation that is error. Ignoring values on the Y axis scalar velocity and angular velocity can be calculated using the following formula:

$$v = \frac{\Delta S}{\Delta T} \quad (6)$$

$$= \frac{\sqrt{(x1' - x1) + (z1' - z1)}}{T2 - T1}$$

$$\omega = \frac{\Delta\phi}{\Delta T} = \frac{\phi 2 - \phi 1}{T2 - T1} \quad (7)$$

The direction of the speed of the moving object is as follows:

$$v = (x1' - x1, z1' - z1) \quad (8)$$

The direction of angular velocity is determined by the positive and negative sign of the value ω.

3. Hardware, Mechanical and Hardware Design

A. Hardware Design

In this research, a robot will be made with a design as shown in the following figure:

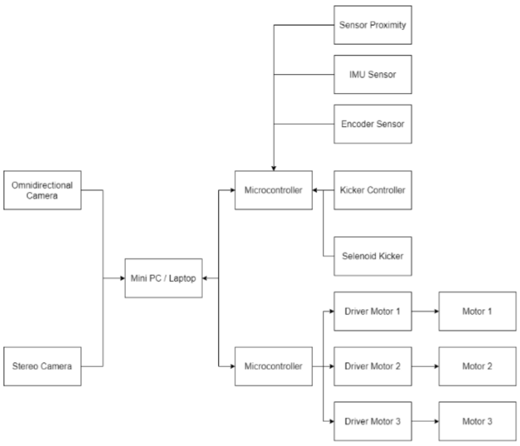

Figure 3. Attacker Robot Hardware Block Diagram.

Figure 4. Goal Keeper Robot Hardware Block Diagram.

Figure 3 and Figure 4 are a block diagram of the attacking robot and the goalkeeping robot. In this study the attacking robot uses 2 cameras as input for the attacking robot, and 1 camera as input for the goalkeeping robot, Mini PC / Laptop as input for the robot goalkeeper. device main and microcontroller as sub control main, proximity sensor, IMU sensor and encoder sensor as input for controller , 3 pieces the driver BLHD50K for attack robots and 4 pieces 3 pieces the driver BLHD50K for goalkeeping robots as sub control DC motor. Selenoid kicker made with copper coils that will be used to kick the ball, as well as 3 Vexta DC motors Brushless BLHHM450K-GFS for attack robots and 4 Vexta DC motors Brushless BLHHM450K-GFS for the goalkeeping robot as its actuator output.

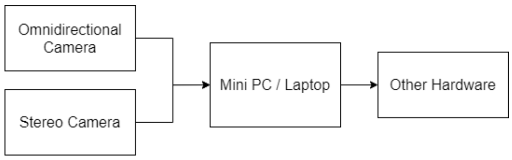

Figure 5. Hardware Block Diagram for Measuring the Position and Velocity of an Object.

In Figure 5, it is explained that the two cameras on the attacking and goalkeeping robots are processed by a Mini PC / Laptop and then will produce a value *the output* in the form of position and *velocity* object, which is *the output* will be used in other hardware systems.

B. Mechanical Design

In this study, attack robots and goalkeeping robots were made by paying attention to the rules in the 2020 Wheeled Football Robot Contest guidebook. So that the attacking robot will use 3 wheels omni wheel, the robot is 48 cm long, 50.2 cm wide, and the robot high is 75 cm, while the goalkeeping robot will use 4 wheels. omni wheel, 52 cm long, 50 cm wide and 80 cm high. As in the picture below:

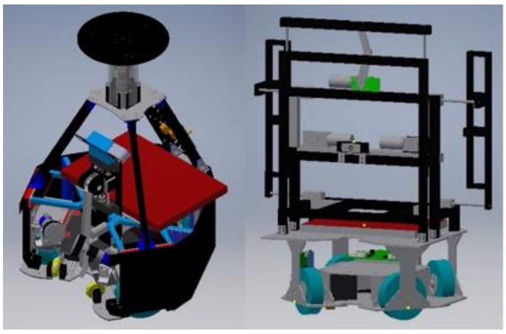

Figure 6. Attacker and Goal Keeper Robot Mechanics Design.

C. Software Design

To support and apply the method to the robot, a software design is needed, as follows flow chart and block diagram robot software:

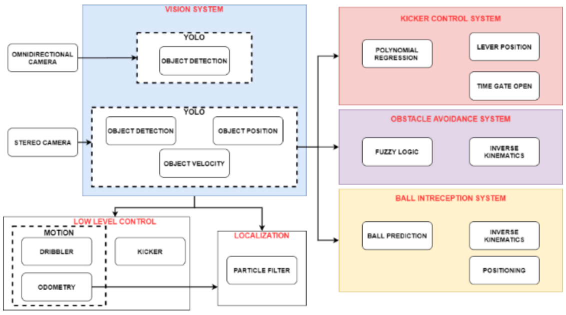

Figure 7. Robot Software System Block Diagram

In Figure 7 is a whole system in the wheeled KRSBI robot. Which one vision system works to manage detection, distance measurement and measurement velocity on the detected object, kicker control system works to regulate the formation of kicks to be kicked by the robot, obstacle avoidance system works to avoid obstacles detected by the robot, and move in a safer direction, then ball interception system work to block the ball that comes to the goalkeeper, localization works to adjust the position of the robot to the field so that the robot knows the position where it is, and low level control works to manage sensor data and robot actuators.

4. Experiments Result

A. Detection System Testing

In this detection system, objects that can be recognized are balls, goals, obstacles (obstacle), costume color cyan, costume color magenta, and goalposts. In the process of testing the detection system is done by comparing the detection results with several existing objects and objects in the field. The objects on the field are orange balls (orange), goal, robot, barrier (obstacle) costume color cyan, costume color magenta, field line, black dot barrier (obstacle), field midpoint, penalty point and point corner (corner).

For the percentage level, the average precision of each object and the percentage Mean Average Precision (mAP) or can be seen as follows.

Table 1. Average Precision and Mean Average Precision Object

Object Class ID	Object Name	*Average Precision (AP)%*
0	Ball	96.36
1	Wicket	97.74
2	*Cyan*	98.59
3	*Magenta*	97.94
4	Obstacle	97.42
5	landmark	87.89
Maps		95% - 99%

In this test, the system will detect the ball object orange, goalposts and goalposts are white with adequate room lighting conditions.

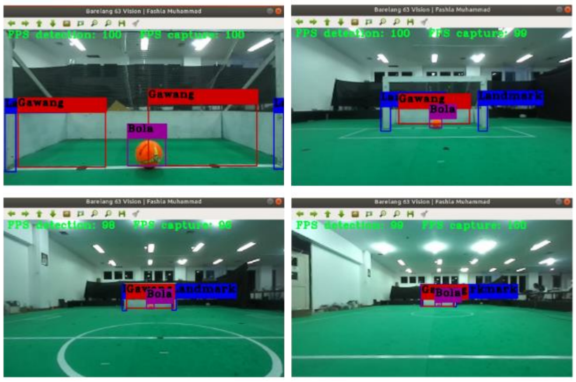

Figure 8. Result of Detection of Ball, Wicket, and Wicket Pole

Information:

- Bounding Box Blue: Wicket Pole
- Bounding Box Red: Wicket
- Bounding Box Purple: Ball Orange

In Figure 8 the detection system is able to detect the three objects with various conditions. Even though there are field lines and black dots in the field, the detection system is still able to distinguish the object you want to detect.

In this test, 15 experiments were carried out for the three objects, in which the detection system was able to detect these objects. The percentage rate of success of the detection system is as follows.

$$P = \frac{15}{15} \times 100\%$$

$$P = 100\%$$

The success rate can be seen P a detection system to detect the ball, goal and goalposts when the object is near, the percentage obtained is 100%. This is because the detected object is still clearly visible, so the system is still very likely to detect it.

B. Orange Ball Distance Measurement System Testing

In testing the ball distance measurement system this time, it is done by placing the ball in front of the camera straight away. The ball is placed from a distance of 1 meter to 9 meters. As a comparison, the results of distance measurements will be compared with manual measurements using a meter. For ball distance values that have been measured using this system are as follows.

Table 2. Ball Distance Measurement Results

No	Actual Distance (cm)	Measuring Distance (cm)	Measurement Error (cm)
1	100	100	0
2	200	200	0
3	300	300	0
4	400	399	1
5	500	499	1
6	600	604	4
7	700	704	4
8	800	795	5
9	900	852	48
		Average Error	7

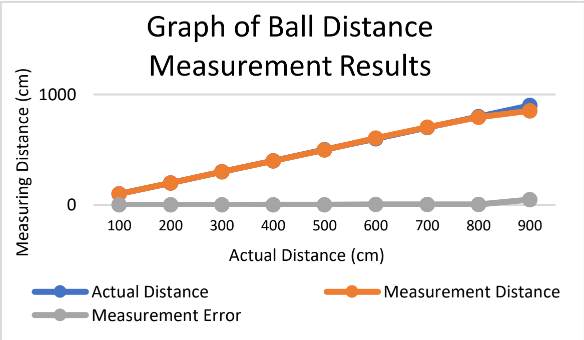

Figure 9. Ball Distance Measurement Graph

Figure 10. Results of Measuring Distance Ball with Close Distance

In Figure 10 the ball measurement system is able to measure and detect the ball well. The distance measurement obtained by the system is 200 cm, in which case the ball is actually 200 cm from the camera. Then the error obtained is 0 cm, this happens because the detected object is still in a close distance and the object is still clearly visible.

C. Velocity Measurement System Testing Orange Ball

Table 3. Measurement Results Orange Ball Velocity

Distance (cm)	Velocity (cm/s)	X Axis Velocity (cm/s)	Y Axis Velocity (cm/s)	X Vector	Y Vector
257	2	-1	1	left	forward
255	4	2	-2	right	backward
258	4	-2	3	left	forward
257	2	1	-2	right	backward
256	0	0	0	-	-
257	2	-1	1	left	forward
255	2	1	-2	right	backward
258	2	-1	2	left	forward
258	2	1	1	right	forward
258	2	-1	1	left	forward
257	16	1	189	right	forward
260	4	-2	3	left	forward
253	8	4	-6	right	backward
215	120	60	-3	right	backward
190	110	55	-3	right	backward
183	118	59	1	right	forward
195	118	59	0	right	-
205	106	53	-16	right	backward
230	84	42	-2	right	backward
264	52	26	22	right	forward
264	0	0	0	-	-

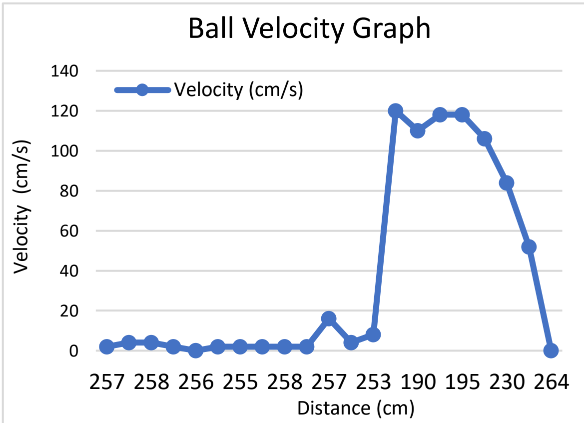

Figure 11. Chart Ball Velocity

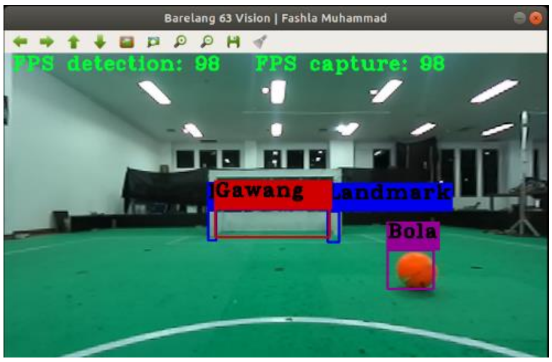

Figure 12. Measurement Results Ball Velocity

In Figure 12 the velocity measurement system is able to detect the speed of the ball moving from the left to the right of the camera with the value obtained is 120 cm / s.

In the velocity graph when the ball is moving, it can be seen that when the ball moves away quickly, the speed will increase, and vice versa when the ball approaches, the speed will decrease. For the value of the direction of the ball on the x-axis at the terminal, it is noted that the ball is moving to the right with an x speed of 60 cm / s, and for the y-axis, the ball is moving closer to the camera with a velocity of y of -3 cm / s.

Conclusion

Based on the tests that have been carried out in the previous chapter, the object detection system is able to detect, measure distances, measure velocity all objects that have been defined by the author, the object distance measurement system is able to measure all objects. The detection system has a mAP percentage of 95.99% for the six objects that can be detected. While the object distance measurement system is carried out by placing the object in front of the camera stereo at a distance of 1 meter to 10 meters, then compared with manual measurements using a meter.

For the percentage of errors in measuring the distance on the ball it has a value of 7 cm, in the goal of 41.11 cm, and the barrier object is 5.11 cm. Next is the measurement system velocity the ball is done by moving the ball in front of the camera. Data velocity can be divided into three, namely moving the ball at a short distance, moving the ball at a moderate distance, and moving the ball at a long distance. Measurement velocity compared to manual measurement using stopwatch.

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